CLAIMS

1. A communications system comprising:

a transmitter for transmitting OFDM/DMT symbols over a predetermined number of bins across a transmission medium, the OFDM/DMT symbols being generated using at least one timing signal, at least one of the predetermined number of bins including a pilot tone sub-symbol having a frequency corresponding to the sampling clock signal;

a receiver for receiving the OFDM/DMT symbols from the transmission medium, the receiver demodulating the received symbols using at least one timing signal, the receiver having a first pilot tone search mode of operation in which the receiver adjusts its timing signal to scan the frequency range corresponding to the predetermined number of bins looking for the pilot tone sub-symbol and identifies the bin including the pilot tone sub-symbol, the receiver further having a subsequent second pilot tone acquisition mode in which the receiver adjusts its timing signal to receive the identified bin containing the pilot tone sub-symbol and measures phase differences between successive pilot tone sub-symbols to thereby perform a further adjustment of the timing signal so that the pilot tone sub-symbols are received within a frequency range sufficient for subsequent phase locked loop processing thereof.

2. A communications system as claimed in claim 1 wherein the timing signal of the transmitter is used for timing inverse Fourier transform processing and for carrier generation in transmitting the OFDM/DMT symbols.

3. A communications system as claimed in claim 1 wherein the timing signal of the receiver is used for timing Fourier transform processing and for carrier generation in demodulating the received OFDM/DMT symbols.

4. A communications system as claimed in claim 2 wherein the timing signal of the receiver is used for timing Fourier transform processing and for carrier generation in demodulating the received OFDM/DMT symbols.

5. A communications system as claimed in claim 1 wherein the receiver computes coherency of sub-symbols received in each bin scanned during the first pilot tone search mode of operation, the receiver rejecting bins having sub-symbols with coherency below a predetermined threshold as not including the pilot tone sub-symbols.

6. A communications system as claimed in claim 1 wherein the receiver computes excessive coherency of sub-symbols received in each bin having a coherency above the predetermined threshold, the receiver rejecting bins having sub-symbols having excessive coherency as not including the pilot tone sub-symbols.

7. A communications system as claimed in claim 1 wherein the bin including the pilot tone sub-symbol is disposed proximate a plurality of proximate bins, the bin containing the pilot tone sub-symbol and the plurality of proximate bins defining a predetermined spectral pattern.

8. A communications system as claimed in claim 1 wherein the receiver identifies the known spectral pattern while in the first pilot tone search mode of operation to assist in identifying the frequency of the bin containing the pilot tone sub-symbol.

9. A communications system as claimed in claim 8 wherein the spectral pattern is symmetric.

10. A communications system as claimed in claim 8 wherein the spectral pattern is asymmetric.

11. A communications system as claimed in claim 1 wherein the OFDM/DMT symbols are transmitted in periodically occurring formatted symbol frames, each formatted symbol frame having a cyclic prefix.

12. A communications system as claimed in claim 11 wherein the receiver adjusts the timing signal in the second mode of operation in accordance with a plurality of operations, the plurality of operations comprising:

computing a sum $S(N)$ of N consecutive pilot tone sub-symbols in accordance with the following equation

$$S(N) = \sum_{l=1}^{N} J(l)\, J^*(l-1)$$

where $J(n+1)$ denotes the $(n + 1)$th complex pilot tone sub-symbol obtained after phase correction for the cyclic prefix and $J^*(n)$ is the complex conjugate of the previously obtained complex pilot tone sub-symbol after phase correction for the cyclic prefix;

obtaining an estimate of a normalized frequency offset ε in accordance with the following equation

$$\hat{\varepsilon} = \frac{1}{2\pi\left(1+\frac{CP}{N}\right)} \operatorname{atan}\left(\frac{Im(S(N))}{Re(S(N))}\right)$$

where CP is the duration of the cyclic prefix in samples;

using the normalized frequency offset to calculate the total frequency offset used to adjust the output of the voltage controlled oscillator.

13. A communications system as claimed in claim 1 wherein the receiver adjusts the timing signal in the second mode of operation in accordance with a plurality of operations, the plurality of operations comprising:

computing a sum $S(N)$ of N consecutive pilot tone sub-symbols in accordance with the following equation

$$S(N) = \sum_{l=1}^{N} J(l)\, J^*(l-1)$$

where $J(n+1)$ denotes the $(n + 1)$th complex pilot tone sub-symbol obtained after phase correction for the cyclic prefix and $J^*(n)$ is the complex conjugate of the previously obtained complex pilot tone sub-symbol after phase correction for the cyclic prefix;

obtaining an estimate of a normalized frequency offset $\hat{\varepsilon}$ in accordance with the following equation

$$\hat{\varepsilon} = \frac{1}{2\pi} \operatorname{atan}\left(\frac{Im(S(N))}{Re(S(N))}\right)$$

using the normalized frequency offset to calculate the total frequency offset used to adjust the output of the voltage controlled oscillator.

14. A communications system comprising:

a transmitter for transmitting OFDM/DMT symbols over a predetermined number of bins across a transmission medium, the OFDM/DMT symbols being generated using a timing clock signal, at least one of the predetermined number of bins including a pilot tone sub-symbol having a frequency corresponding to the timing clock signal;

a receiver for receiving the OFDM/DMT symbols from the transmission medium, the receiver comprising

a demodulator for receiving the OFDM signals at a selectable

reception frequency determined by a frequency control signal and for converting received OFDM/DMT symbols to digital data samples in accordance with a sampling clock signal, the sampling clock signal having a frequency that is responsive to a sampling clock control signal,

a controller circuit including a first output signal connected to provide the frequency control signal to the demodulator circuit and a second output signal connected to provide the clock control signal to the demodulator, the controller including a first pilot tone acquisition mode of operation in which the clock controller (i) directs the demodulator to scan at least a portion of the plurality of bins by varying the frequency control signal to the demodulator, (ii) uses the digital data samples from the demodulator to identify which of the plurality of bins includes the pilot tone, the controller further including a second pilot tone acquisition mode in which the controller (i) provides a frequency control signal to the demodulator to direct the demodulator to receive the bin including the pilot tone as identified in the first pilot tone search mode, and (ii) uses the digital data samples from the demodulator to provide a frequency control signal to the demodulator so that the

demodulator receives the bin containing the pilot tone within a frequency range sufficient for subsequent phase locked loop processing of the pilot tone whereby the frequency and phase of the sampling clock signal of the receiver is responsive to the phase locked loop processing to thereby synchronize the sampling clock of the receiver with the timing clock signal of the transmitter.

15. A communications system as claimed in claim 14 wherein the demodulator comprises:

a voltage controlled oscillator responsive to the frequency control signal, the voltage controlled oscillator having an output signal of variable frequency that is adjustable in response to the frequency control signal; and

a frequency synthesizer responsive to the output signal of the voltage controlled oscillator for generating a demodulating carrier signal that determines the selectable reception frequency.

16. A communications system as claimed in claim 14 wherein the demodulator comprises:

a voltage controlled oscillator responsive to the sampling clock control signal, the voltage controlled oscillator having an output signal

of variable frequency that is adjustable in response to the sampling clock control signal; and

a sampling clock signal generator for generating the sampling clock in response to the output signal of the voltage controlled oscillator.

17. A communications system as claimed in claim 14 wherein the demodulator comprises:

a voltage controlled oscillator responsive to the frequency control signal, the voltage controlled oscillator having an output signal of variable frequency in response to the frequency control signal;

a frequency synthesizer responsive to the output signal of the voltage controlled oscillator for generating a demodulating signal that determines the selectable reception frequency;

a clock signal generator for generating the sampling clock in response to the output signal of the voltage controlled oscillator; and

the sampling clock control signal and the frequency control signal being a common signal.

18. A communications system as claimed in claim 14 wherein the controller uses the digital data samples of the demodulator to compute squared

magnitude values to identify the bin containing the pilot tone while in the first pilot tone acquisition mode of operation.

19. A communications system as claimed in claim 14 wherein the controller uses the digital data samples of the demodulator to compute coherency of symbols received in each bin of the at least one portion of the plurality of bins that are scanned during the first pilot tone acquisition mode of operation, the controller rejecting bins having coherency below a predetermined threshold as not including the pilot tone.

20. A communications system as claimed in claim 14 wherein the controller uses the digital data samples of the demodulator to compute excessive coherency of symbols received in each bin having a coherency above the predetermined threshold, the controller rejecting bins having excessive coherency as not including the pilot tone.

21. A communications system as claimed in claim 14 wherein the bin including the pilot tone is disposed proximate a plurality of proximate bins, the bin containing the pilot tone and the plurality of proximate bins defining a predetermined spectral pattern.

22. A communications system as claimed in claim 14 wherein the controller uses the digital data samples of the demodulator to identify the known spectral pattern while in the first pilot tone acquisition mode of operation.

23. A communications system as claimed in claim 22 wherein the spectral pattern is symmetric.

24. A communications system as claimed in claim 22 wherein the spectral pattern is asymmetric.

25. A communications system as claimed in claim 14 wherein the controller uses the digital data of the demodulator to calculate phase differences between consecutive pilot tone sub-symbols to adjust the demodulator in the second mode of operation.

26. A communications system as claimed in claim 14 wherein the OFDM/DMT symbols are transmitted in periodically occurring formatted symbol frames, each formatted symbol frame having a cyclic prefix.

27. A communications system as claimed in claim 26 wherein the controller uses digital data samples of the received OFDM/DMT signals to adjust the demodulator in the second mode of operation in accordance with a plurality of operations on the digital data samples, the plurality of operations comprising:

computing a sum $S(N)$ of N consecutive pilot tone sub-symbols in accordance with the following equation

$$S(N) = \sum_{l=1}^{N} J(l) J^*(l-1)$$

where $J(n+1)$ denotes the $(n + 1)$th complex pilot symbol obtained after phase correction for the cyclic prefix and $J^*(n)$ is the complex conjugate of the previously obtained complex pilot symbol after phase correction for the cyclic prefix;

obtaining an estimate of a normalized frequency offset ε in accordance with the following equation

$$\hat{\varepsilon} = \frac{1}{2\pi\left(1 + \frac{CP}{N}\right)} \operatorname{atan}\left(\frac{Im(S(N))}{Re(S(N))}\right)$$

where CP is the duration of the cyclic prefix in bins;

using the normalized frequency offset to calculate the total frequency offset used to adjust the output of the voltage controlled oscillator.

28. A communications system as claimed in claim 14 wherein the controller uses digital data samples of the received OFDM/DMT signals to adjust the demodulator in the second mode of operation in accordance with a plurality of operations on the digital data samples, the plurality of operations comprising:

computing a sum *S(N)* of *N* consecutive pilot tone sub-symbols in accordance with the following equation

$$S(N) = \sum_{l=1}^{N} J(l)\, J^*(l-1)$$

where $J(n+1)$ denotes the $(n + 1)$th complex pilot symbol obtained after phase correction for the cyclic prefix and $J^*(n)$ is the complex conjugate of the previously obtained complex pilot symbol after phase correction for the cyclic prefix;

obtaining an estimate of a normalized frequency offset $\hat{\varepsilon}$ in accordance with the following equation

$$\hat{\varepsilon} = \frac{1}{2\pi} \operatorname{atan}\left(\frac{Im\,(S\,(N))}{Re\,(S\,(N))}\right)$$

using the normalized frequency offset to calculate the total frequency offset used to adjust the output of the voltage controlled oscillator.

29. A communications system as claimed in claim 14 wherein the controller comprises a digital signal processor.

30. A communications system comprising:

a transmitter for transmitting OFDM/DMT symbols over a predetermined number of bins across a transmission medium, the OFDM/DMT symbols being generated using at least one timing signal,

at least one of the predetermined number of bins including a pilot tone having a frequency corresponding to the sampling clock signal;

a receiver for receiving the OFDM/DMT symbols from the transmission medium, the receiver demodulating the received symbols using at least one timing signal, the receiver having a first pilot tone search mode of operation in which the receiver adjusts its timing signal to scan the predetermined number of bins looking for the pilot tone and identifies the bin including the pilot tone, the receiver further having a subsequent second pilot tone acquisition mode in which the receiver adjusts its timing signal to receive the identified bin containing the pilot tone and performs a further adjustment of the timing signal so that the pilot tone is received within a frequency range sufficient for subsequent phase locked loop processing thereof.